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Development of a Small Boat Deployment and Recovery System for Fiber Optic Acoustic Arrays

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Abstract - The Small Boat Deployment System (SBDS) was developed for the Mobile Inshore Underwater Warfare System Upgrade (MIUW-SU) program to deploy and recover two acoustic arrays and 8-km (4.3 nm) of fiber optic/electrical trunk cable from a 6.7 m (22-ft) Boston Whaler outboard motor boat. The arrays are part of a transportable surveillance system for guarding near shore assets that integrates visual, thermal, radar, EMS and acoustic data.

The SBDS consists of a tension limited hydraulic winch, a flexible boom, line thrower, precision GPS navigation system, and acoustic release. The hydraulic winch is controlled by an adjustable relief valve to limit tension during deployment and retrieval. Tension control is needed for preventing damage to the fiber optic cable and for a proper deployment. A flexible boom acts like a fishing pole to even out the dynamic loads caused by boat motion. A line thrower is used to shoot a messenger line over the surf zone to shore. The precision GPS is needed to guide the boat along a predetermined route. An acoustic release is used to recover the array.

The development program consisted of testing two experimental prototypes and then combining features from both for the final production system. The first prototype tested tension limited controls on a commercially available hydraulic winch and were used to deploy and recover a 10-km (5.4 nm) cable and array from a 15 m (50-ft) boat. The second prototype used a small capacity electric winch for testing procedures and components on a 6.7-m (22-ft) boat. The production system will be tested on a variety of boats with different shore and sea conditions.

The SBDS will be delivered to MIUW units in Jan. 96.

INTRODUCTION

Currently, NCCOSC RDT&E Division is developing the Mobile Inshore Underwater Warfare-System Upgrade (MIUW-SU) Small Boat Deployment System (SBDS) for rapidly deploying an array sensor system in shallow water (less than 183-m (600-ft)) up to 16-km (8.6 nm) offshore. The arrays are part of a transportable surveillance system for guarding near shore assets that integrates visual, thermal, radar, ESM and acoustic data, see figure 1.

Design Goals

1. Maximum water depth is 183 m (600 ft).
2. Deploy in up to sea state 3 and recover in up to sea state 2.
3. Use 6.7-7.6 m (22-25 ft) outboard motor boat or larger craft of opportunity for deployment.
4. Array to be recoverable from ocean end.
5. Easily used and maintained by Navy Reservists.
6. Deploy at 4 knots (4 hrs for baseline configuration deployment) and recover at 2.5 knots (6 hrs for recovery).
7. Limit maximum tension to less than 114 kg (250 lbs).
8. Easily transportable in C-141 airplane.

The system needs to be easily deployable in up to a sea state 3 to increase its operational window. The recovery crew can wait for a calmer sea state 2 to recover. The maximum

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tension is limited by maximum installation load of the fiber optic cable.

DEVELOPMENT

The main design driver was reducing the weight of the deployed array and handling system to fit on a 6.7-m (22-ft) boat. This meant that the trunk cable had to be the lightest proven design consistent with a 2-12 month survivability. The handling system had to limit loads to less than 110 kg (250 lbs) tension to avoid damaging the cable. The handling system had to have some means of limiting tension.

There were two prototype systems that were tested before the production system was built. The first prototype system was the continuation of the development of an experimental small boat deployment system that used a small 12 VDC capstan motor. It had a flexible boom for compensating for the dynamic loads introduced by the boat motion, and used split reels to separate the non-uniform diameter array from the uniform diameter trunk cable. The maximum winch tension was limited to 50 lbs. Any loads higher than that caused the belt drive to slip. Level winding was by a boat hook.

This first prototype and various deployment procedures were tested by reservists. This prototype verified use of the flexible boom; use of a precision GPS navigation system; the use of a line thrower to get the cable to the beach over the surf zone; and verified that the boat was stable with a 360-kg (800-lb) cable weight.

As a result of testing, it was decided that the system had to be safer to work around. A safety cage and automatic level wind were recommended. Design studies showed that it was not possible to use a 12 VDC motor to recover the system with 91-kg (200 lbs) tension at 2.5 knots. The production winch was required to use a hydraulic motor.

The second prototype system was built to deploy 1700-kg (3740 lbs) of arrays and cable. The MIUW-SU program needed to deploy a long term training array which would be in the water up to 5 years. Once deployed, the array would be used to train the MIUW crews on the sonar processor. It had to be more robust than the

production array due to the longevity requirement. The handling system did not have to fit in a 6.7-m (22-ft) boat, but it was desirable to be small size to fit on a 15-m (50-ft) boat to lower the deployment costs.

A deployment winch based on a commercially available hydraulically powered reel stand was developed with a pressure relief valve for limiting the tension. The relief circuit could limit tension from 23 to 900 kg (50 to 2000 lbs).

This second prototype was used to deploy in Sep 94 and recover in Jan 95 two arrays with 10-km of trunk cable. A swimmer was used to swim a messenger line ashore. This system verified the design of the hydraulic relief circuit; the use of a split drum; the use of a small acoustic release for recovery; and the use of precision GPS to lay the arrays with a straightness within 0.47 m (1.5 ft). The deployment and recovery also indicated the levels of tension needed during the different phases of the deployment and recovery for the production system.

DEPLOYMENT AND RECOVERY PROCEDURES

When the MIUW-SU system is needed, it will be flown and driven to its operational site. Prior to shipment, the sites for the shore station, array locations and cable route will be determined, and the cable reel will be wound with the appropriate lengths of trunk cable and arrays. The production system will be deployed (see figures 2 and 3) as follows:

1. Shoot or float a messenger line past the surfline onto a beach or pass the line to a pier.
2. Pull the shore cable to the shore from the boat.
3. Deploy the trunk cable.
4. Deploy the arrays and lowering line.
5. Deploy acoustic release.

The trunk cable will be deployed with 9-14 kg (20-30 lbs) of tension. The arrays will be deployed with 70 kg (150 lbs) of tension to ensure that they are completely stretched out. The arrays do not have to be absolutely straight, but they can't be in a heap on the bottom.

Reference acoustic sources will be placed near the arrays to calibrate them for processing.

In some instances, arrays will need to be placed at further distances from shore and a multi-stage deployment will be needed. A first stage of 8-km (4.3 nm) of cable and arrays will be deployed and a line with a buoy will be tied to the array. The boat will then return to shore and replace the cable reel with a loaded one. The boat will recover the buoyed end of the array to make a quick connection and then will continue with the additional cable and arrays.

The recovery is the reverse of the deployment. The acoustic release will be triggered to bring the lowering line to the surface and then the array and trunk cable will be recovered. The recovery tension will vary from 23-91 kg (50-200 lbs) depending on the depth, amount of cable burial in the mud and the cable recovery speed. If the cable gets snagged, the boat will maneuver to try to free it. If unable to free it by maneuvering, the cable will be pulled up to the 270-kg (600-lb) breaking strength of the cable until it is freed or the cable breaks. If the cable breaks, an attempt will be made to recover the remaining cable and array from the shore end. After recovery, the cable and arrays will be refurbished at the depot.

UNDERWATER SENSOR STRING

The sensor string consists of the several modules that can be combined for different configurations. The modules are the 4-km trunk cable, array, shore cable/cathode, and anode. Figure 4 shows the 370-kg (810-lb) baseline configuration (2 arrays and 8-km of trunk cable), which is the maximum weight that can be deployed in one boat trip. The sensor string can have up to 4 arrays and 16-km (8.6-nm) of trunk cable. The sensor string uses a sea water return between the cathode and anode to eliminate a conductor in the trunk cable. Each module has quick connect, dry mateable, Rochester Electro-Light connector ends.

The trunk cable module consists of a 4-km (2.15 nm) length of 3.35-mm (0.132-in) diameter. Rochester Electro-Light armored trunk cable. The trunk cable has a single optical fiber and a single electrical conductor with a break strength

of 273-kg (600 lbs), an installation load of 114-kg (250 lbs) and a minimum bend radius of 7.6 cm (3 in).

The array module consists of a 38.67-m (127-ft) length of array with 32 hydrophones, and a 5.8-kg (12.8-lb) telemetry node. The node is 12-cm (4.75-in) in diameter and is the largest diameter component of the underwater sensor string.

The shore cable/cathode module consists of a 400-m (1310-ft) length of 7.62-mm (0.30-in) diameter. Northern Telecom armored shore cable with a single optical fiber and two electrical conductors and a 6.8-kg (15-lb) cathode bottle. The shore cable has a break strength of 1360-kg (3000 lbs) to withstand the more violent conditions in the surf zone.

The anode weighs 6.8 kg (15 lbs) and has a mechanical eye for attaching the lowering line.

SYSTEM DESCRIPTION

The SBDS consists of a tension limited hydraulic winch, a flexible boom, line thrower, precision GPS navigation system, and acoustic release, see figure 5. SBDS weight is 345 kg (760 lbs). Total system weight including the cable and three crew is 980 kg (2160 lbs). A boat operator, winch operator, and deckhand are required to operate the SBDS. They will be cross trained to rotate duties.

The tension limited InterOcean hydraulic winch weighs 186 kg (410 lbs). The winch is controlled by an adjustable relief valve to limit tension between 9-90 kg (20-200 lbs) during deployment and retrieval. Tension control is needed for preventing damage to the fiber optic cable and for a proper deployment.

The winch has an easily changed reel, a safety cage with the control console mounted on it, an automatic level wind, and a disk brake. The reel is 90 cm (36 in) diameter and is split between a 0.61 m (24 in) wide section for the trunk cable and shore cable and a 24 cm (9.5 in) wide section for the arrays and the lowering line. The reels can be exchanged in less than 15 minutes. The reel and winch frame are marine grade aluminum. The safety cage can be opened like a clam shell to get access for reel exchange.

The winch controls are direction and speed, relief valve setting with a pressure gage, and relief valve bypass. The relief valve bypass is needed for free wheeling the reel during deployment of the shore cable and handling the array. The disk brake is powered by a hand pump and is independent of the winch hydraulic system. It can be used as a drag control as a backup mode for deploying the system if there is a failure in the hydraulic system. The winch has a safety pin for locking the reel rotation while attaching and removing the telemetry, cathode and anode bottles from the reel flange.

A 5.5 HP gasoline powered HydraTech hydraulic power unit (HPU) with a pressure compensated variable volume provides winch power. The HPU and winch are joined by quick disconnect, no leak, connectors.

A flexible boom acts like a fishing pole to even out the dynamic loads caused by boat motion. The boom consists of two telescopic fiberglass poles made by Skypole and a fairlead for guiding the cable. The 5.1-cm (2-in) diameter poles have a 30 cm (1 ft) flex for 140 kg (300 lbs) load. The poles are telescopic to allow retraction of the fairlead for clearing debris. The 30.5-cm (12-in) diameter stationary fairlead is made out of nylon tube and Ultra-High Molecular Weight (UHMW) plastic. The UHMW was chosen for high abrasion resistance.

A Mossberg Line Thrower is used to shoot a messenger line over the surf zone to shore. The line thrower has a range of 250 m (820 ft). The 250-m (820-ft) range is needed to allow the boat to keep a safe distance from the surf zone.

A precision GPS is needed to guide the boat along a predetermined route. The SBDS will be using a Precision Lightweight GPS Receiver (PLGR). The PLGR is a portable (1.25 kg (2.75 lbs)) GPS receiver with a security module for providing precision GPS readings. For comparison, the standard (commercial) GPS has a horizontal accuracy of 100 m (330 ft) versus the precision GPS accuracy of 10 m (33 ft). The PLGR can store up 100 waypoints and combine them into a route. The PLGR guides the boat along the route track by giving a display of distance off the track and which side of the track.

Other required navigation equipment items are a compass and a depth sounder. The depth sounder has a shallow water warning for working in the surf zone.

An acoustic release is used to recover the array. The PLGR will be used to mark the position where the release is dropped, and then guide the boat back to that position. A deck unit will be used to acoustically trigger the release to bring the lowering line to the surface. The release will be either be a modified reference acoustic source or a commercial unit.

The MIUW units will practice deployments and recoveries with a non-functional training array. It will have the same weight and size characteristics as the production array except that the trunk cable modules will be 2 km (6560 ft) long to allow a deployment and recovery exercise in one day.

STATUS

The preliminary testing of the components is complete. Final testing of the SBDS will be in the summer of 1995. Items that will be tested with a training array are:

1. Installation of array in up to sea state 3.
2. Installation of array onto sandy beach, rocky beach and pier.
3. Single stage and multiple stage deployments and recoveries.

The SBDS will be used to deploy and recover a production array in the fall of 1995. Two SBDS will be delivered to reserve units in early 1996.

RESULTS AND CONCLUSIONS

The MIUW-SU program has demonstrated the techniques and components needed to deploy and recover a lightweight array with a small boat. Testing of the production system will verify that all of the design goals have been met.

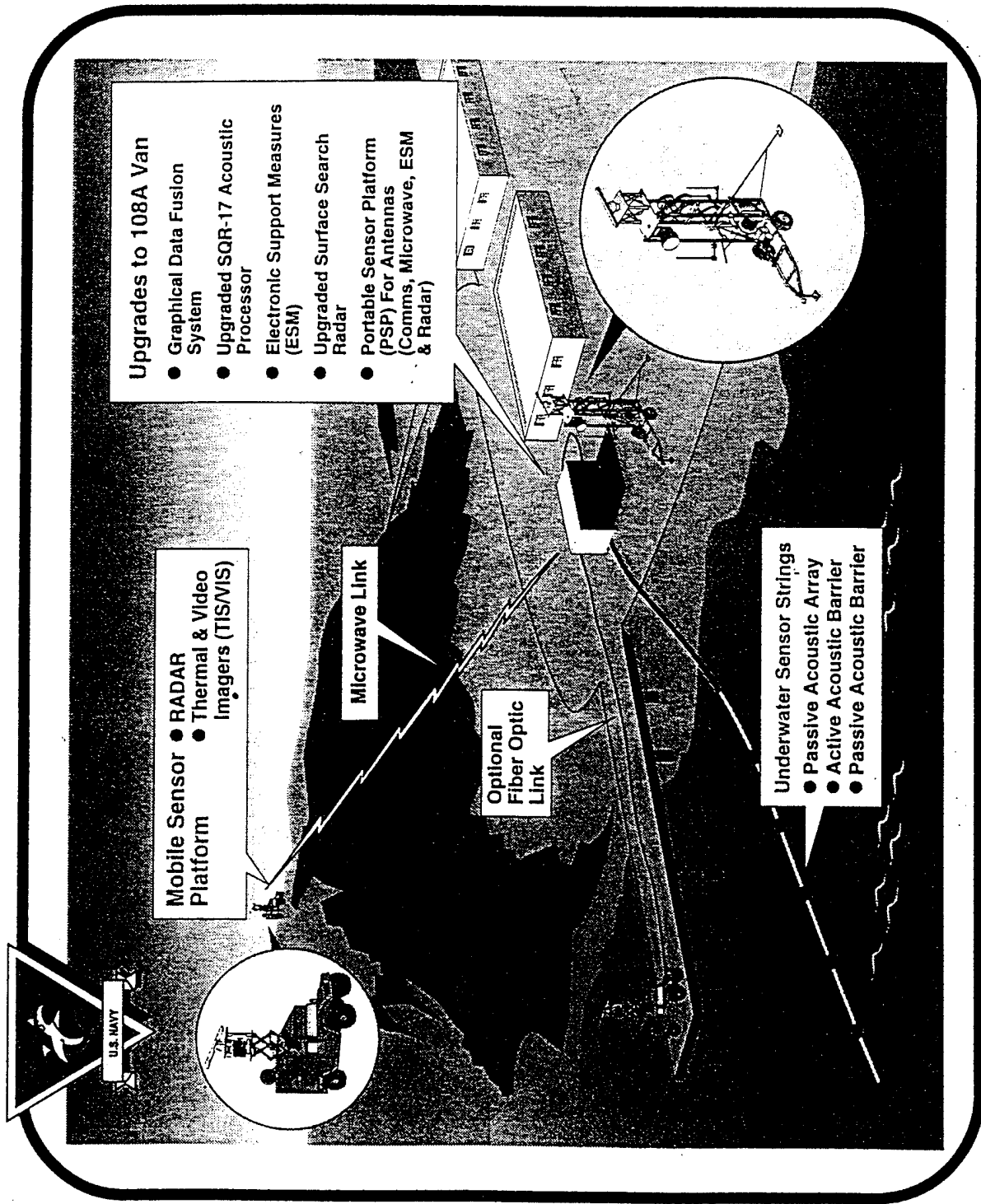
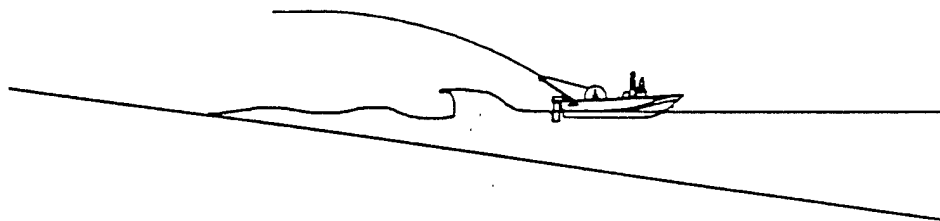
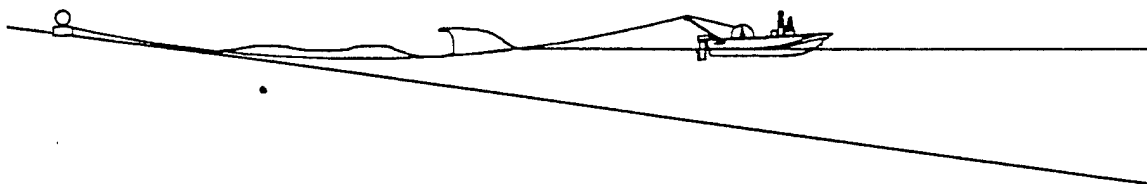


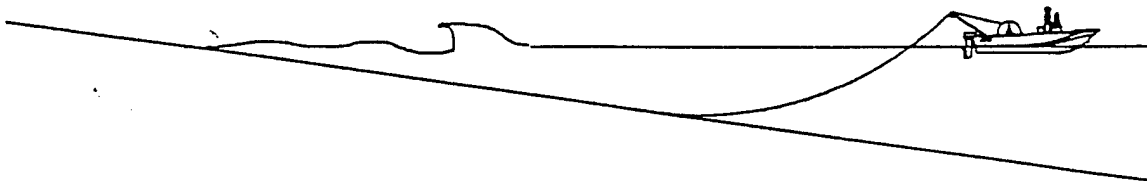
Figure 1 Mobile Inshore Undersea Warfare System Upgrade



1. SHOOT MESSENGER LINE TO SHORE

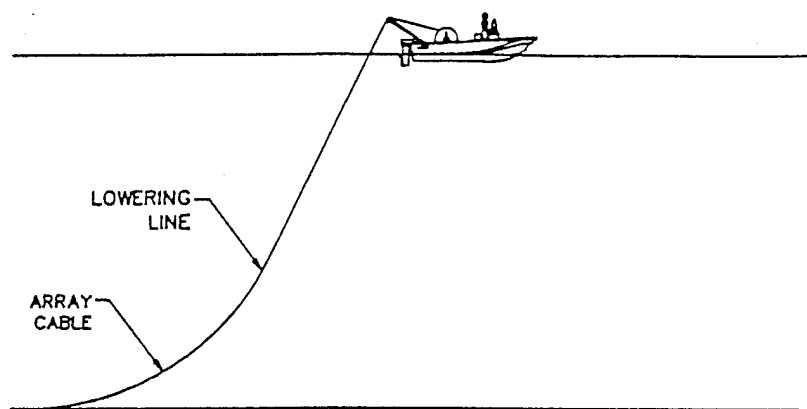


2. PULL SHORE CABLE FROM SHORE

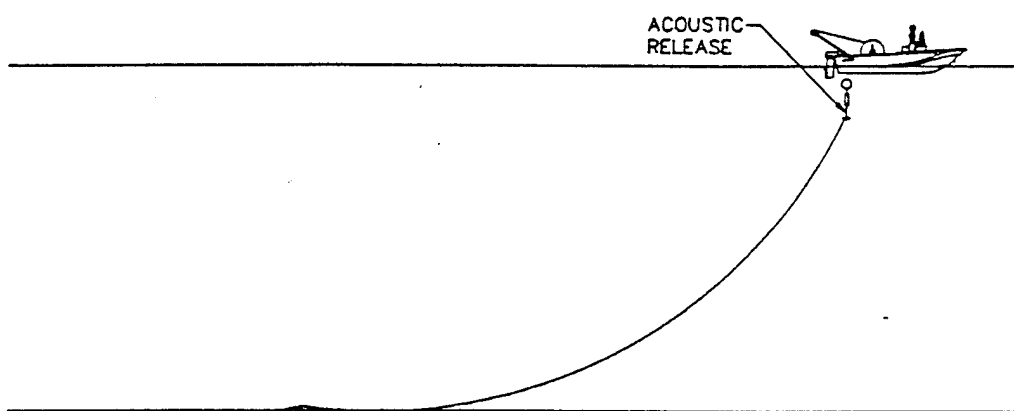


3. DEPLOY TRUNK CABLE

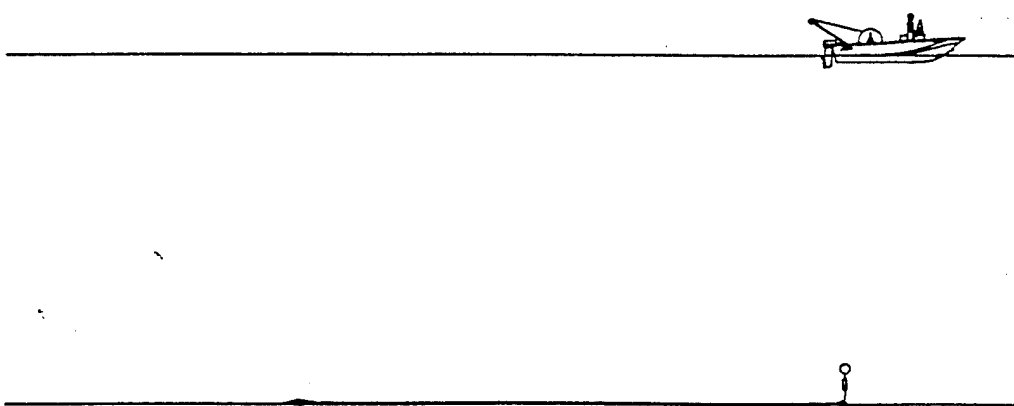
Figure 2 Deployment procedure



4. DEPLOY FINAL ARRAY AND LOWERING LINE



5. DROP ACOUSTIC RELEASE



6. ACOUSTIC RELEASE ON BOTTOM

Figure 3 Deployment procedure (cont'd)

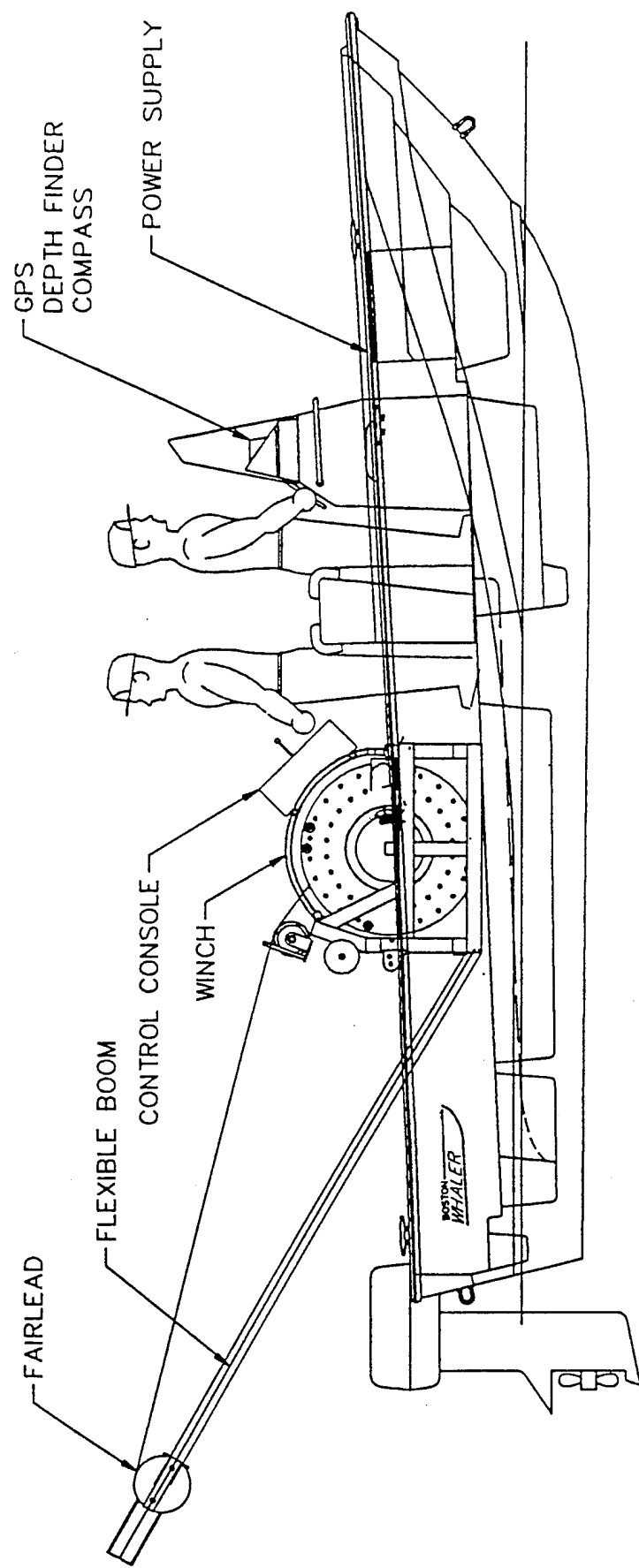


Figure 5 MIUW-SU Small Boat Deployment System